"UNCONVENTIONAL SUPPLIES" AND THE WATER DISPUTE AMONG THE RIPARIANS OF THE JORDAN RIVER WATERSHED

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ABSTRACT

Proposed resolutions to the Arab-Israeli water conflict that fail to consider the introduction of alternative freshwater sources in the not-too-distant future cannot be taken seriously. Each of three major forms of freshwater supply augmentation (the "unconventional supplies") is likely to be implemented on a widespread basis in the region, thereby substantially altering the regional water balance. These unconventional supplies are desalination, water imports, and the reclamation of wastewater. This paper assesses the relevance of the unconventional supplies in achieving regional accommodation over shared and scarce freshwater, with particular attention to the advantages, disadvantages, and complexities introduced by wastewater reclamation.

INTRODUCTION

The water resources shared by Israel, Jordan, the Palestinian Territories, and Syria[1] are not sufficient to meet human freshwater demand. The shared waters in question include the Jordan River and its tributaries, several coastal rivers whose watersheds encompass both Israeli and Palestinian territory (See Figure 1), and two aquifer systems whose hydrologic boundaries straddle the "Green Line," the border between the West Bank and Israel proper (See Figure 2). Annual human use of the region's water resources currently surpasses the "safe" or *sustainable*[2] annual freshwater yield by nearly 500 MCM/annum. Future deficits are projected to range from 800 MCM to 3.4 x 10^9 m^3 (BCM)/annum by the year 2040 (NAS, 1999). The scarcity of freshwater in the region, compounded by (1) the impairment of existing resources by a variety of pollutant inputs, and (2) the historic political tension among the riparian neighbors, makes the Arab-Israeli case one of the most seemingly intractable water disputes to be found anywhere.

Many insightful analyses of the Arab-Israeli water dispute have examined competing claims for existing resources (as well as the evolution and legitimacy of these claims) and the distribution of scarcity among the inhabitants of the region. Hillel (1994) places the question of Middle East water scarcity in its proper natural scientific and historical context. The proceedings of the first international conference on the Arab-Israeli water conflict (which took place in Switzerland in 1992) are presented by Isaac and Shuval (1994). Lonergan and Brooks (1995) provide a comprehensive interdisciplinary analysis of the conflict that highlights, among other obstacles, the difficulties associated with poor data sharing and availability. Lowi (1995) offers an analysis informed by the theories of power dynamics and interstate behavior in the international relations literature, while Wolf (1995) examines the degree to which water scarcity may have driven political and military decisionmaking (the so-called "hydraulic imperative"). Abouali (1996) offers a criticism of the current distribution of water resources based on several bodies of international law. Allan (1996) points out that the international food trade has had an important influence on the regional water conflict because cereal and vegetable imports amount to imports of "virtual water." (Virtual water is the water manifest in agricultural products. Imported grains or vegetables can – indeed, should – be thought of as imported water. This point is particularly noteworthy since food self-sufficiency in the region, given even present populations, is simply not a possibility. Food self-sufficiency in the lands of Israel, Jordan, the Palestinian territories, and the portions of southwestern Syria located within the Jordan-Yarmuk watershed would require an annual freshwater stock of some 7.2 x 10^9 m^3 (BCM), a value well above the renewable volume of freshwater that is available even in years of extremely high precipitation.[3]) Elmusa (1998) offers an additional political-economic perspective as well as revisiting the unratified yet influential Johnston agreement. Haddad and Feitelson (Haddad et al. 1999; Haddad and Feitelson 1997; Haddad and Feitelson 1994a; Haddad and Feitelson 1994b) coordinated five years of policy-oriented research on an aquifer system whose hydrologic boundaries span the border between the West Bank and Israel proper, concluding that cooperative Israeli-Palestinian management represents a genuine win-win solution for the riparians. More focused work by Feitelson and Abdul-Jaber (1997) examines varying institutional approaches to jointly managing wastewater in the region of Jerusalem and its environs.

Municipal Demand Management Will Not Resolve the Shortfall.

Water availability in the region of the Jordan River watershed is replete with uncertainty, based largely on extreme climatic variability. Over the past century, the coefficient of variation for total annual precipitation falling over Israel, the West Bank, and Gaza, defined as the sample standard deviation divided by the interannual mean, is approximately 25 percent (Stanhill and Rapaport 1988).

One uncertainty is that total water demand in the region is likely to rise with population. The only eventuality that could precipitate a leveling off (or even decline) in demand is a decline in per-capita water use whose magnitude offsets the concurrent increase in population. Such a scenario will occur only with a massive allocation shift of water away from irrigated agriculture to municipal and industrial users. At the same time, the sudden and complete diversion of water away from irrigated agriculture to other uses is neither likely nor necessarily desirable, since agriculture represents an established way of life for a significant fraction of the regional population as well as a form of open-space protection in much of the region, particularly coastal Israel.[4]

Relative to the rest of the world, water use in the Middle East is quite low. While gross mean per-capita water consumption differs substantially among Israel, Jordan, and the Palestinian territories (as well as Syria, assuming its consumption patterns in the Yarmuk basin are generally similar to those of its Jordanian neighbor), the regional mean value is extremely low, at ~95 m^3/annum (NAS 1999). Israel, whose consumption is by far the highest among the countries in question, uses an estimated 330 m^3/annum (NAS 1999), half the global average (Gleick 1993). Hillel (1994) reports that agricultural water use efficiency is exceedingly high in the study area, particularly in Israel, relative to other parts of the world, due to the widespread application of drip and microsprayer irrigation technology. Meanwhile, mean gross non-agricultural water use in the study area is ~80 m^3/annum – nearly a fifth below minimum water requirement for mixed domestic and industrial needs proposed by Shuval (Shuval 1992).

On the one hand, the implementation of water conservation measures in all sectors remains a sensible policy. It has been estimated that freshwater demand in Israel could be reduced by as much as 15-20 percent (GTZ and Engineers 1996), an equivalent reduction of some 280-390 MCM/annum based on 1997 consumption data reported by the Israeli Hydrological Service (State of Israel 1999). Potential for water use reductions also exists on the Jordanian side in the form of increased irrigation efficiency (through drip and microsprayer systems) and improvements to the water delivery infrastructure. The latter is also a critical policy matter for the Palestinians. "Unaccounted-for" water amounts to well over 50 percent of water consumption in Jordan and between 40 percent and 50 percent in the Palestinian territories (GTZ and CES Consulting Engineers 1996). In some cases these are bonafide losses through pipe leakage but in others, the term "loss" is misleading since the unaccounted-for volume is explained by un-authorized connections to the distribution system. The "loss" is an economic loss to the state (or independent water utility, whatever the case may be) but it does not represent "wasted" water since the missing flow is ultimately reaching human end users.

Figure 3 (See Figure 3) indicates the *present* extent of freshwater shortfall – approximately 500 MCM/annum – based on the estimates of freshwater availability in the region and most recent estimates of water consumption. Two important dynamics must be gleaned from the figure. First, as discussed above, the bar on the right side of the balance will inevitably rise as the *conventional* water sources on the left side of the balance will remain fixed. Second, there is substantial uncertainty associated with water availability based on climatic variability, as mentioned above. Human use is responsive to these climatic variations, but not in a linear way. Policy response to drought in Israel, for example, is as follows: allocations to urban users remain unchanged on a per-capita basis while voluntary municipal conservation campaigns are put in place. Agricultural water outlays, on the other hand, are substantially reduced, though not in a direct inverse relationship with rainfall. In Jordan, water scarcity is so acute that municipal use is rationed during the summer. These policy responses are not sufficient to meet expected increases in demand. Thus we must also turn to supply augmentation as a means of alleviating freshwater scarcity. This requires looking past "virtual water" imports to alternative sources of freshwater, such as desalination (of both seawater and brackish water), direct water imports from outside of the immediate region, and the reclamation of treated wastewater. The purpose of this paper is to highlight the importance of these alternative or "unconventional" sources of water, particularly with respect to how the implementation of wastewater reclamation could bear on the water relations among the riparians of the Jordan River watershed.

THE "UNCONVENTIONAL SUPPLIES": AN OVERVIEW

Seawater Desalination**.**

Desalination generally refers to any engineered process that removes dissolved solids (salts) from seawater, brackish water, or treated wastewater. According to the State of California, 60 percent of the global desalination capacity is currently situated in the Persian/Arabian Gulf region (California Coastal Commission 1999), where freshwater scarcity is severe and substantial petroleum-derived capital is available. Throughout the rest of the Middle East (including the Jordan River watershed and its environs), implementation of desalination technology has been limited by its economic cost relative to the economic cost of "available" alternatives (such as groundwater, even as aquifer resources are extracted at rates surpassing that of recharge).

There are two principal technologies for desalination: distillation and membrane treatment (such as nanofiltration and reverse osmosis). Distillation involves evaporating water under high temperatures and pressures and then capturing the re-condensed and desalted steam. Membrane treatment describes the process of forcing saline water through an extremely fine filter that retains the salts. In each case, the outputs of the desalination process are twofold: (1) relatively fresh product water with total dissolved solids (TDS) concentrations ranging from 1 to 500 parts per million (ppm) and (2) highly salt-concentrated waste brine. The volume of freshwater product relative to the volume of input water is often referred to as the "recovery" rate. For seawater desalination facilities, the recovery value generally ranges from 15-50 percent, which is to say that generally, greater than half of the volume of input seawater is returned as waste brine with salinities far higher than that of seawater. Recovery values tend to increase as the salinity of the input water decreases; recoveries for brackish water and treated wastewater desalination, for example, are well above those for seawater.

Largely by virtue of its energy requirements, economic costs of seawater desalination are extremely high. The State of California reports that the full-time operation of the Santa Barbara, California reverse osmosis facility for seawater desalination, which was designed to desalinate 9.3 MCM/yr to 300 ppm TDS at approximately 45 percent recovery, would require approximately 50 million kWh/yr. The State asserts that this value is roughly double the energy requirement for importing water to the California coast from the Colorado River, several thousand miles away. Seawater desalination is several orders of magnitude more energy-demanding than oil refining or steel production, whose typical energy requirements for small to midsize facilities are somewhere around 100,000 kWh/yr (California Coastal Commission 1999).

Estimates of the real economic costs for providing freshwater from conventional sources in Israel, for example, range from \$0.30-\$0.70/m^3 in 1996 dollars, as compared with between \$0.70/m^3 (GTZ and CES Consulting Engineers 1996) and \$1.50/m^3 (in 1993 dollars) for desalination of water whose TDS concentration is greater than 5000 ppm (Lonergan and Brooks 1995). In California, seawater desalination costs are estimated to vary from \$0.80 to \$3.20/m^3 (California Coastal Commission 1999).

As demand for freshwater increases with population, and technical innovation lowers costs, desalination technology is becoming more competitive with other sources, particularly as freshwater demand outpaces conventional supplies. Indeed, the Israeli lay press has already quoted officials at Mekorot, the Israeli government water company, as arguing that the agency could produce desalinated water from the Mediterranean for under \$0.70/m^3 (Cohen 2000b).

Increasing the scale of a proposed facility can vastly reduce the unit cost of desalination, but it will also require massive initial capital investment. The Israelis have already begun appeals for foreign assistance in the production of an extremely large-scale seawater desalination plant: an 800 MCM/annum facility that would be the world's largest by a factor of four (Makovsky 1999).[5] The largest existing seawater desalination plant located in Saudi Arabia has a capacity of approximately 180 MCM/yr.

Indeed, the possibility of construction of such a giant desalination facility forces a radical rethinking of the management of water resources in the Jordan watershed region in general. Until very recently, water resources development among the riparians of the Jordan River was treated almost uniformly as a domestic affair.[6] Israel constructed its National Water Carrier to deliver water from the Sea of Galilee to its coastal population centers, for example, while Jordan built its King Abdullah (East Ghor) Canal to provide water from the

Yarmuk River to Jordanian farmers on the east bank of the Jordan River. (*De facto* states of war precluded genuine cooperative management, although the Unified Plan offered by American envoy Eric Johnston in 1955 came surprisingly close.)

The notion of installing a large and expensive seawater desalination facility along the Israeli coast is inconceivable without some degree of multilateralism, or what Patricia Wouters (2000) has referred to as "hydrosolidarity." In its initial efforts to procure foreign aid for desalination, Israel has actually floated the idea of the facility being a truly regional one, serving not only Israel but also Jordan and the Palestinians (Makovsky 1999). Large-scale multilateral water planning of the kind in present discussion represents a true departure from previous policy. An even more dramatic feature of the desalination option is that it would clearly be optimized by the redistribution of large portions of the inland water resources away from Israel back to the Arab riparians, while Israeli users along the coast would consume the desalinated supply. The logic for such a redistribution would be the massive energy savings associated with gravity-powered delivery of water from source to consumer (See Figure 4).

The possibility of the construction of a regional seawater desalination facility will require a level of technical cooperation largely unseen in the region to date. For example, in the event that the Sea of Galilee becomes a reservoir principally for Jordanian or Palestinian freshwater consumption while remaining sovereign Israeli territory, Israel must be reasonably expected and counted upon for proper stewardship of the lake and protection of its quality. This expectation can only be conditioned on trust and genuine good relations far beyond what have been demonstrated in Israeli-Jordanian or Israeli-Egyptian relations up to the time of this writing. Without a doubt, it will require major revisions of existing water agreements between Israel and Jordan and the Palestinians, respectively, with more focused attention to be paid to water quality protection.

<u>Water Imports</u>**.**

Discussions of actual (as opposed to virtual) water imports to the Middle East from regions blessed with "surplus" water resources have abounded in recent years. The conveyance of water may be achieved either through overland transport (via pipeline) or marine transport (via tanker, vinyl bags, or submerged pipeline). (See Figure 5) The GTZ and CES Consulting Engineers (1996) present diversion options to Israel and/or the Palestinian territories from the Manavgat and/or Seyhan-Ceyhan Rivers (Turkey), the Litani River (Lebanon), and the Euphrates River (Iraq). For exceedingly obvious political reasons, the import of water from the Iraqi reaches of the Euphrates cannot be expected to occur in the foreseeable future, nor can it necessarily be assumed that the Iraqis enjoy a dramatic water surplus (Beaumont 1998). A transfer from the Litani River[7] is only slightly more imaginable, assuming a successful conclusion of peace agreements between Israel and Syria and Lebanon, respectively.

Imports from Turkey, however, are currently the topic of high-level political discussion between the Israeli and Turkish governments and can be considered a distinct possibility. At the time of this writing, an Israeli team of water managers had just concluded a series of negotiations with the Turks for the purchase of 45 MCM/annum of freshwater between 2001 and 2003. The pending purchase has been described by the Israeli negotiators as an "emergency measure" to meet demand until desalination facilities can be completed, ostensibly by 2003 (Cohen 2000b). Though the Turks are likely to sell the water from the Manavgat River for under $\$0.10/m^3$, the full economic cost of the import will reach at least $\$0.85/m^3$ once taxes and tariffs, shipping, processing at each port, and connection to the Israeli National Water Carrier are included. Given these high costs relative to Mekorot claims of seawater desalination costs, the Israeli parliament has begun to consider legislation requiring the immediate planning of desalination facilities.

Even before verifying that desalinating Mediterranean seawater can be achieved at the costs that Mekorot claims, one may question the logic of transporting vast amounts of freshwater to the region on other grounds. Presumably, the import is meant to relieve agricultural irrigation demand as much as municipal demand. Importing water at relatively high cost, even while the import of additional cereals and vegetables (virtual water) is possible at a fraction of the economic cost, is indeed difficult to justify on efficiency grounds. The frequently-offered response in the region, as intimated above, is that choosing virtual water over actual water imports would incur a substantial social cost among farm communities. Increased crop imports – as a substitute for water imports – would be doubly damaging to local agriculture in that it would also introduce increased competition.

<u>Wastewater Reclamation.</u>

What is frequently left out of discussions of both desalination and water imports is that the increase of the upper bound on water availability that results from the exploitation of the unconventional supplies causes a resultant increase in the production of wastewater, and the subsequent availability of treated wastewater as an alternative source of freshwater. A variety of technologies exist for treating both domestic and industrial wastewater to levels sufficient for non-potable, or with considerably more expense, potable reuse. In Israel, the volume of reclaimed wastewater reached 250 MCM in 1994 with the overwhelming majority of that used to irrigate crops. This value represents an impressive 65 percent of the combined domestic/municipal/industrial sewage stream (Eitan 1995).[8] (Note however that 20-30 percent of non-irrigation freshwater distributed to end-users never reaches the sewer system.)

A CAUTIOUS APPROACH: THE SUPPLY AUGMENTATION POTENTIAL AND POSSIBLE ENVIRONMENTAL COSTS OF WASTEWATER RECLAMATION

The operative term in this context is "non-irrigation." As mentioned above, agricultural irrigation is the dominant use of freshwater in Israel and Jordan. The water used to irrigate crops cannot be substantially reclaimed because, where high-efficiency drip and microsprayer irrigation systems are largely in place, most irrigation water is either incorporated into plant biomass or evapotranspired. No more than about 15 percent of the total volume of freshwater extracted by Israel for human use is reclaimed for reuse. The equivalent regionwide percentage in 1994 (again, excluding Syria) was well under 10 percent, a lower figure because wastewater reuse is currently less established in Jordan and negligible in the Palestinian areas.

The GTZ and CES Consulting Engineers (1996) estimate that the volume of additional wastewater available for reclamation projected out to the year 2040 is nearly 1.5 BCM/annum (p. 17). A more realistic figure is approximately 1 BCM/annum, still a mighty amount.[9] To place this volume in proper context we must take note of the GTZ/CES projections of total human water demand in the region in 2040. The range of values offered is 4.3-5 BCM/annum. Based on these projections and the above calculation of wastewater reclamation potential, it appears as though it may be possible to more than double current rate of sewage reclamation.

Risk and Opportunity.

The option of recycling wastewater is not without its dangers. Substantial attention has been paid to the human health risks associated with sewage irrigation, largely via infection by parasitic and to a lesser degree, bacterial pathogens (Shuval and Fattal 1999; Cifuentes 1998; Shuval et al. 1997; Shuval et al. 1989; Shuval et al. 1986; Camann et al. 1983; Clark et al. 1981; Sanchez-Levya 1976). This research, along with additional work on pond systems (Mara and Pearson 1999; Mara et al. 1992; Mara and Cairncross 1989), has demonstrated that virtually any properly designed treatment system can reliably treat municipal sewage to safe levels for both restricted and unrestricted irrigation, at least with respect to pathogenic and oxygen-demand parameters.

Salinity, however, remains a difficult problem. Indeed, the otherwise effective low-cost pond/reservoir systems that are in such widespread use throughout the region actually tend to increase the salinity of the effluent. Prominent voices in the region have attempted to bring the salinity problem to the attention of planners and the public with indeterminate success. A former Israeli Water Commissioner argues that irrigating crops with treated wastewater whose chloride concentrations surpass 400 ppm ought to be banned due to the threats that such saline water poses to groundwater quality, soil quality, and crop yields (Zaslavsky 1999). Others argue that salinization of soils is a function of irrigation generally and is not particular to irrigation with wastewater. In their view, irrigation with treated sewage – indeed, irrigation with any waters of higher salinity – may be permissible so long as proper drainage and water management practices are applied (Shevah 2000).

Salinity removal has not been a traditional design objective of wastewater treatment engineering but it is likely to become a standard feature of treatment systems in arid regions in years to come. Treated wastewater in the region can be thought of as brackish water, containing TDS concentrations in the low (1-5) parts per thousand (ppt) range. The economic cost of desalinating brackish water has been estimated at about half that of desalinating seawater (GTZ and CES Consulting Engineers 1996; WRI 1992; Glueckstern 1991), and the sources of exploitable wastewater are well distributed throughout the region (spatially), whereas seawater must be conveyed at great distances and up dramatic topographic gradients to reach consumer centers.

It must be recalled, however, that desalination technologies do not recover the full volume of the input water (see above). Depending on the influent salinity, the recovery rate for wastewater is some 60-90 percent, with the filtrate requiring disposal as waste brine. Thus, depending on the extent of the implementation of desalination facilities for sewage reclamation, the potential for wastewater recovery may be substantially reduced (while effluent qualities are improved).

THE GEOPOLITICAL CHARACTER OF THE UNCONVENTIONAL SUPPLIES GENERALLY AND WASTEWATER RECLAMATION IN PARTICULAR

A First General Concern: Bilateralism.

Water management plays an important role in both the existing agreements between Israel and Jordan and Israel and the Palestinian Authority, as well as in the ongoing negotiations between Israel and the Palestinian Authority and between Israel and Syria.

Despite the fact that the water resources under discussion encompass Israeli, Jordanian, Palestinian, and Syrian jurisdictions and that there is a committee on water in the multilateral component of the Middle East peace process, each of the substantive agreements on water to date have resulted from bilateral (as opposed to multilateral) negotiations. Although the bilateral format has until now been more effective at achieving agreements, a shortcoming of the approach is that important third parties in multiriparian basins are left out of the resolutions. Simply put, the pie tends to be divided without all the consumers present at the table. The Israel-Jordan Treaty of Peace is an example of such an agreement, with the waters of the Yarmuk tributary and the mainstem of the Jordan distributed between Israel and Jordan as though Syria and the Palestinians were not riparians to the watershed. In sum, the only challenge to *unilateralism* in water development in the region has been *bilateral*, rather than basin-wide *multilateral* agreement.

A Second General Concern: Ignorance of Variability.

The practice of allocating fixed volumes among riparians, rather than allocating percentages of variable flow over some defined time period is a problematic characteristic of the existing Arab-Israeli water agreements. In the Israeli-Jordanian case, for example, Jordan is presently allocated 30 MCM each summer from the upper Jordan River downstream of the outlet of Sea of Galilee, 20 MCM of which it receives in return for Israel's extractions of 20 MCM from Yarmuk tributary in winter (Israel-Jordan Treaty of Peace 1994 (Annex II, Articles I.1.b and I.2.a,d.)). This volume, combined with an additional 25 MCM/annum that Israel guaranteed the Jordanians under the terms of an agreement reached between King Hussein and former Prime Minister Netanyahu at Aqaba in May 1997 (CNN 1997), amounts to a total fixed volume of 55 MCM/annum.[10] Since, as discussed above, streamflow varies as function of rainfall, the proportion of the annual yield that this volume represents will differ substantially from year to year. Thus, in years of low precipitation, intense disputes are likely to result from lower-than-average streamflow, as occurred in the spring of 1999 following two consecutive winters of extremely low precipitation. A diplomatic crisis resulted from Israel's initial decision to deny Jordan portions of the latter's summer allocation, ostensibly due to the formers inability to extract its winter share from the Yarmuk due to low precipitation in the winter of 1999. Although the dispute was resolved through quiet negotiation (CNN 1997) and the Israelis eventually provided Jordan with the volume it demanded, the dispute would have been avoided entirely if the treaty's water sharing had been based on percentages of annual discharge rather than on fixed volumes.

Cooperative Management, Variability, and Seawater Desalination.

These new supplies have a significant bearing on both cooperative management and attention to climatic variability in the resolution of water disputes. To begin with, the introduction of the unconventional supplies changes the size and makeup of the theoretical pie to be divided among the riparians through water diplomacy, forcing a rethinking of the potential of joint water management policy. Furthermore, these supplies tend to be far less susceptible to climatic variability than conventional sources.

The idea of cooperative water management in the region (and in other conflicted watersheds throughout the world) has been championed by academics and practitioners for decades, and can be traced at least as far back as John Wesley Powell, a nineteenth century American naturalist and explorer who was among the earliest critics of unrestrained settlement of whites in the American West:

> [American] states bothered Powell . . . their borders were nonsensical . . . boxing out landscapes, sneering at natural reality, they were wholly arbitrary . . . in the West, where the one thing that really mattered was water, states should logically be formed around watersheds . . . to divide the West up any other way was to sow the future with rivalries, jealousies, and bitter squabbles . . . (Reisner 1986).

Although the joint management approach has historically been judged by negotiators as impractical in the Middle East context, a recent Israeli newspaper report is worth citing as evidence of a possible sea change:

> Israel is proposing that a regional water agency in charge of financing, planning, and developing

> water resources be established in the Middle East. Foreign Minister David Levy proposed … to his Jordanian counterpart, Abad el-Ayala Hatib, that a meeting be arranged so that experts from Israel and Jordan have a chance to discuss the idea (Benn 2000).

This piece failed to point out that Minister Levy was referring strictly to "new source" development and not those waters historically exploited by the region's riparians. Even so, Levy's declaration is an encouraging indication that Israel, the dominant riparian power, has a new willingness to pursue development of the unconventional supplies in a cooperative and regionally integrated way. The emerging importance of the unconventional supplies is yet another argument for a shift away from the standard zero-sum game analysis of the Arab-Israeli water dispute. Additionally, procuring foreign assistance for the construction and operation of coastal desalination works will almost certainly be conditioned on regional technical cooperation and the guarantee that increased freshwater supplies will also benefit the Palestinian territories and Jordan.

As for the question of variability: one of the great advantages of desalination is that it is not climate dependent. Desalination-derived water supply is guaranteed year-round. Thus, when desalinated water is considered in water-sharing or water-allocation agreements, actual volumes *can* be reasonably divided. As discussed above, the same is not true for rainfall-dependent conventional supplies, for which proportions of annual discharge are really the only sensible parameter to apportion. In the event that desalinated seawater is considered as part of the regional freshwater stock, then their distribution among the riparians ought to be considered separately from the conventional supplies.

While the temporal reliability of seawater desalination is obviously a major advantage of the technology, it may become a complicating factor in water diplomacy. However, the redistribution of supplies that involve the exchange of a non-climate dependent source with a dependent one will create complications. The participants in water diplomacy might add reliability (climate independence) to simple volumes as a negotiation objective.

<u>Wastewater Reclamation and Water Diplomacy.</u>

With respect to variability and the reliability of supply, wastewater reclamation lands somewhere in the middle. Indeed, the supply of treated wastewater will necessarily track human water consumption. The stock will drop only as municipal consumption drops, which is inconceivable barring radical unforeseen circumstances. As to how reclaimed wastewater must be considered in this regard in water agreements, apportioning raw volumes is likely *not* a useful guide unless planners can agree that they can accurately predict water consumption trends several years into the future. Otherwise, dividing proportions of the sewage generated each year (like dividing proportions of annual freshwater yield) is the most sensible approach.

Before considering the question of wastewater reclamation and joint water management, we must be clear about the fact that the wastewater will play an increasing role in the regional water balance in coming years. Conflicts over sewage are taking on a substantially different character in Israel and Palestine than they do almost anywhere else in the world.

When a country discharges wastewater into a transboundary river or stream sending it into the territory of a downstream neighbor, the resultant conflict generally tends to be over the responsibility for pollution abatement. The grievance of a downstream riparian is that an upstream neighbor is polluting its waters. *Under conditions of extreme freshwater scarcity, however, wastewater ceases to be thought of strictly as a disposal problem and begins to assume the character of a scarce resource.* The operative question is transformed from: "whose responsibility is wastewater treatment?" to "who enjoys the benefit of treated wastewater?"

As populations rise and the amount of wastewater generated by human communities continues to rise, the stock of available treated wastewater rises in parallel. There is an increase in the availability of treated wastewater in absolute terms, but also, and more importantly, an increase relative to the limited and stable availability of conventional water supplies.[11] In other words, treated wastewater is likely to become a much larger relative component of the total available freshwater stock in coming decades.

At present, treated wastewater represents a form of supply augmentation for non-potable[12] uses such as agricultural irrigation, thereby freeing up for direct human consumption the conventional freshwater formerly utilized in agriculture. As the present Middle Eastern drought extends into a third year, Israel may join Jordan and the Palestinian territories in rationing municipal freshwater consumption, even as Israel reduces agricultural allocations of freshwater by 60 percent. The Israeli press cites that in the near future, all Israeli irrigation is to draw against reclaimed wastewater exclusively, with conventional freshwater and desalinated seawater to be reserved for the cities (Cohen 2000a).

For the Palestinian population, whose present agricultural consumption of freshwater of any kind is miniscule (although substantially higher in Gaza than in the West Bank), the availability of reclaimed wastewater represents the opportunity for agricultural development of previously marginal areas. Rather than discharge municipal wastewater into wadi bottoms in the West Bank or into the Mediterranean (from the Gaza Strip), treated effluent could be used in the cultivation of a variety of foodstuffs and commercial crops.

On the other hand, since so little conventional freshwater is used in Palestinian agriculture, no substantial drinking water offsets via wastewater irrigation can be expected from sectoral shifts within the Palestinian areas alone. Instead, augmentation of the Palestinian municipal drinking water supply via wastewater reclamation can only occur through the provision of conventional freshwater supplies freed up by the availability of treated sewage to Israeli agriculture. *In other words, the drinking water supply augmentation potential of treated wastewater in the Palestinian areas is contingent upon water management coordinated between the Israelis and the Palestinians*.

Reuse of wastewater depends on proper storage and conveyance. In Israel, reuse occurs in one of two ways. In the first, effluent from a centralized urban wastewater treatment facility, such as the Shafdan facility serving the Tel Aviv metropolitan area, is transported via pipeline to agricultural consumers elsewhere in the country. In this situation, the producers and consumers of wastewater are separate entities. In the Yizre'el Valley just southwest of Haifa, for example, effluent from Haifa's wastewater treatment plant is pumped approximately 5 km over gradual sloping terrain and is stored in a series of ponds for irrigation by farm collectives outside of the city. In this and other similar cases, consumers of treated sewage must purchase the resources from its producers.

In the second scenario, small communities convey their wastewater to their own reservoirs for combined treatment and storage.[13] Then, the treated wastewater is conveyed directly over short distances to fields for irrigation. In this format, producers of wastewater consume their own sewage via local agriculture. As of 1994, as much as 50 percent of the wastewater in Israel (by volume) was reclaimed in this way (Eitan 1995).

To relieve extreme drinking water scarcity in the Palestinian territories, one reasonable solution may be for Israeli communities downstream of Palestinian cities to exploit Palestinian sewage in return for conventional freshwater (albeit not necessarily on an equivalent volumetric unit basis). There are a variety of creative water exchanges that could be formulated if water were to be managed in a truly integrated way. Indeed it has been convincingly demonstrated that cooperative management at the watershed level has great potential to produce synergistic gains (Cohon and Marks 1973).

At the same time, one must acknowledge the difficulty in predicting the nature of the final regional accommodation that will be achieved between Israel and the Palestinians (let alone Israel and Syria). Reconciling the principle that "good fences make good neighbors" with the very real advantages of cooperative water management will surely be a difficult one.

In the meantime, however, a number of joint wastewater reclamation projects may be developed as confidence-building measures. Two are offered below.

In the first, a substantial proportion of the wastewater from Jerusalem flows eastward, untreated, through the Wadi Nah'r/Nahal Kidron drainage toward the Dead Sea (See Figure 6). The current situation there is characterized by wasted freshwater, wasted nutrients, and a threat to public health. A similar case exists in the northern West Bank, where untreated sewage flows westward towards Israel proper from Nablus (See Figure 7).[14] In each case, the wastewater possesses a transboundary character in that it either (1) crosses a real or proposed jurisdictional boundary or (2) originates from sewer systems serving with mixed Palestinian and Israeli populations (as is in the case at Wadi Nah'r). The advantages of cooperative reclamation measures to the Palestinian side include Israeli financial contribution, Israeli technical expertise (based on several decades of wastewater reclamation in Israel proper), the production of substantial additional freshwater for agricultural purposes, and the reduction of the nuisance and public health hazard of raw sewage flowing through its territory. The Israeli interests include, in addition to the production of additional freshwater and the reduction of public health and ecological threats, confidence-building measures for normalization of relations.

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ENDNOTES

[1] Syria is often irresponsibly left out of discussions of the Arab-Israeli water conflict. Indeed, a substantial portion of the streamflow of the Yarmuk tributary to the Jordan River is contained within Syrian territory and the Syrian exploitation of the headwaters of the Yarmuk at the al-Wehda Dam was estimated to range from 80 to 120 MCM/annum in 1994 (GTZ and CES Consulting Engineers 1996) and may have risen as high as 200-220 MCM/annum in 1998 (M. Yzraeli, personal communication January 2000). Lebanon must also be considered a riparian to the watershed since one of the headwaters to the Upper Jordan River, the Hazbani springs, lie within its territory. However, since Lebanon is not suffering from water scarcity at anywhere near the intensity of that suffered by the other riparians, it is left out of the present discussion.

[2] Aquifers (as opposed to surface waters) may be extracted at greater than 100 percent of annual recharge. The word "sustainable" refers in this context to withdrawals of groundwater at rates no higher than that of recharge, thereby insuring that existing groundwater levels are maintained.

[3] In statistically rare years of extremely high precipitation, the total annual renewable freshwater stock for the region may reach 4 BCM. The demand value of 7.2 BCM assumes that the Syrian population dependent on the waters of the Yarmuk River is 500,000 and that the per-capita water requirement for food self-sufficiency is 560 m^3/annum, as estimated by Cohen (1995).

[4] In the West Bank, Palestinian agriculture remains primarily rainfed, partly due to Israeli restrictions on Palestinian water use since 1967. The gradual transfer of West Bank territory to Palestinian control has increased Palestinian irrigation, but the proportion of Palestinian water used in irrigated agriculture is still under 5 percent of total water use.

[5] Recall that the 9 MCM/yr Santa Barbara RO facility would consume 50 million kWh/yr if operated continuously. This means that an 800 MCM/yr facility, even with the benefit of innovation and economies of scale, will consume energy at a rate of several hundred million kWh/yr.

[6] The Israel-Jordan Treaty of Peace distributes the yield of the Upper Jordan River basin in such a way that requires the linking of instructures so that water can be transferred from the Sea of Galilee to Jordanian conveyance to Amman. See the Treaty's Annex II, Articles I.1.b and I.2.a,d.

[7] For discussion of the possibility that Israeli diversion of the waters of the Litani may already have taken place, refer to Amery (1998; 1993) and Wolf (1998).

[8] This combined sewage volume includes Jewish settlements in the West Bank and Gaza as well as portions of several of larger Palestinian cities whose sewer systems are included in the wastewater management survey published by the Israeli government.

[9] Assume that close to all of the wastewater produced by the human communities of the region can be exploited for reuse in either agricultural or urban irrigation as well as an aggregated regional sewage production figure of 40 m^3/capita/annum. This figure is a population-weighted average that has been adjusted based on the following additional assumptions: 20 percent of freshwater distributed to non-agriculture users is either incorporated, evapotranspired, or returned to surface and groundwaters without reaching the sewer system; and existing "un-accounted for" water rates (15 percent in Israel, 55 percent in Jordan, 40 percent in the West Bank, and 50 percent in Gaza) will remain unchanged over the next four decades. If we also assume that per capita freshwater consumption rates will also remain

constant, then we may very simply estimate the available reclaimed wastewater volume to equal 40 m^3/annum multiplied by the regional population in any given year. A mid-range population prediction for the study area for the year 2040 is 28 million. (Note that this analysis, too, excludes the Syrian component.)

[10] The 1997 Aqaba agreement stipulated that the transfer of the flow to Jordan would last for a period of three years, although there is a reasonable possibility that Israel will agree to continue the transfers indefinitely.

[11] The term "stable stock" is, of course, a bit of a misnomer because of the extreme variability in rainfall on an interannual basis.

[12] Improving the quality of effluent from irrigation-grade to drinking water-grade is neither technically challenging nor particularly expensive, but there is not yet a readiness on the part of the public to accept that drinking directly recycled sewage, when properly treated, is completely safe.

[13] For detailed description of hybrid pond/reservoir treatment systems, see Mara and Pearson (1999) and Juanico and Dor (1999).

[14] In the cases of both Nablus and Jerusalem, the city lies on the watershed divide, and sewage flows both eastward and westward into two different watersheds. The eastern drainage of Nablus, Wadi Fara, is not considered in this paper since it is likely that the bulk of the territory through which the stream flows will be under Palestinian jurisdiction following the final status agreement between Israel and the Palestinian Authority. Similarly, the western drainage of Jerusalem, Nahal Sorek, flows almost entirely through Israel and is currently treated and reused within Israel.

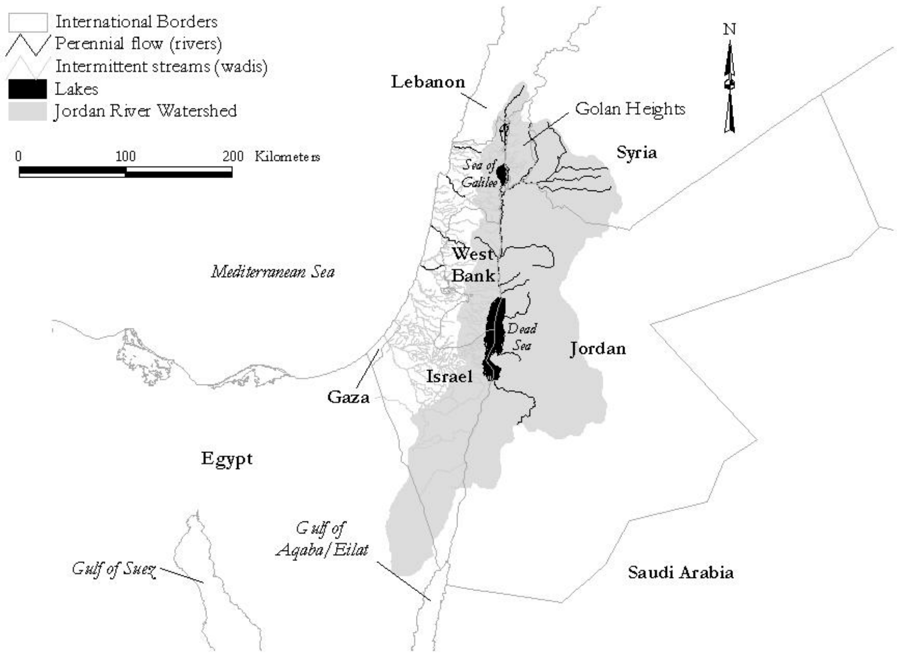

Figure 1. The surface water resources of the Jordan River watershed along with the shared Israeli-Palestinian coastal drainages.

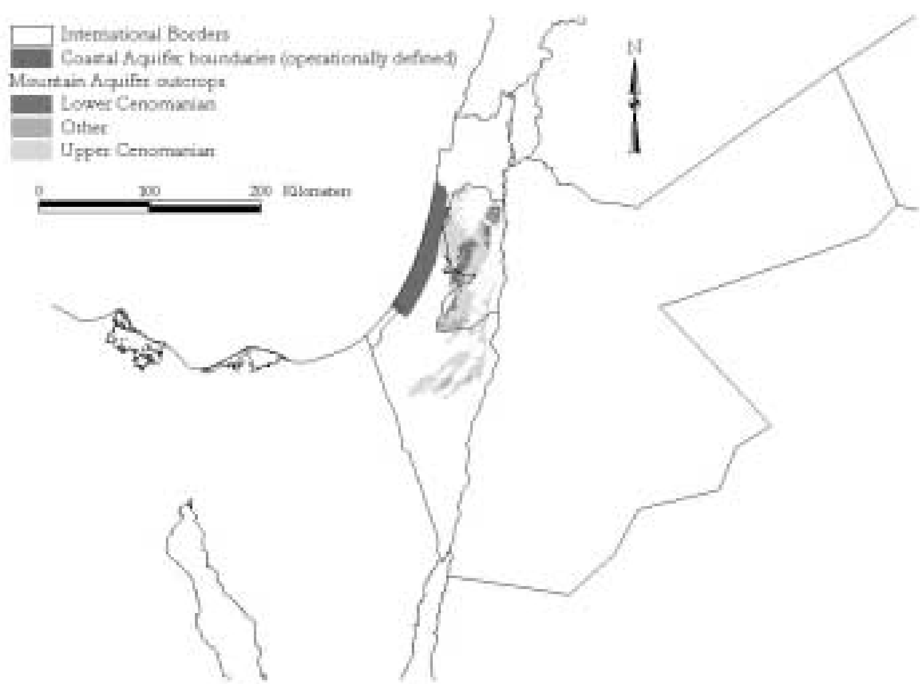

Figure 2. The major groundwater resources available to the riparians of the Jordan River watershed.

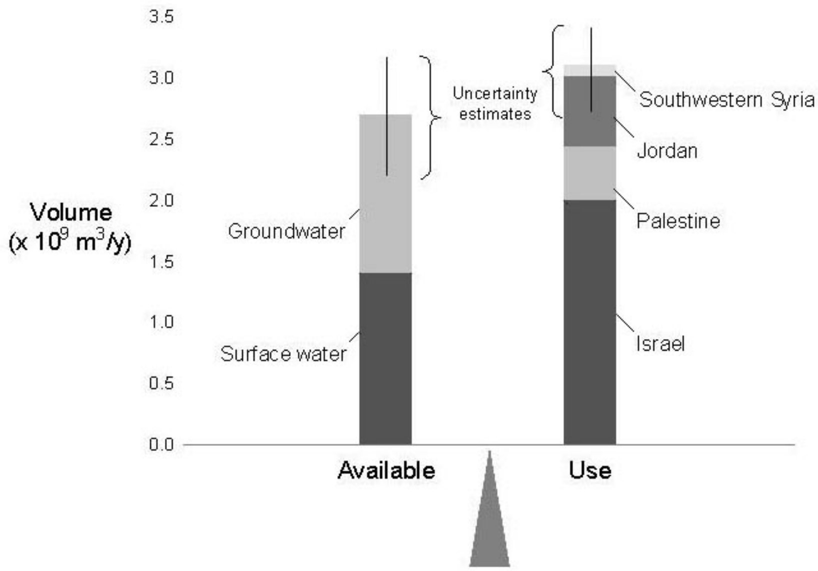

Figure 3. Crude water balance diagram. Water use figures are for the year 2000, estimated by multiplying multi-year average per-capita consumption data for each country by population estimates for the year 2000. The uncertainty range for water availability is derived from an assumed 25% coefficient of variation for rainfall over the region. The uncertainty range for water use is based on its non-linear relationship with water availability. Syrian water use assumes a population of 500,000 in the Yarmuk basin utilizing 200 m^3/capita/annum.

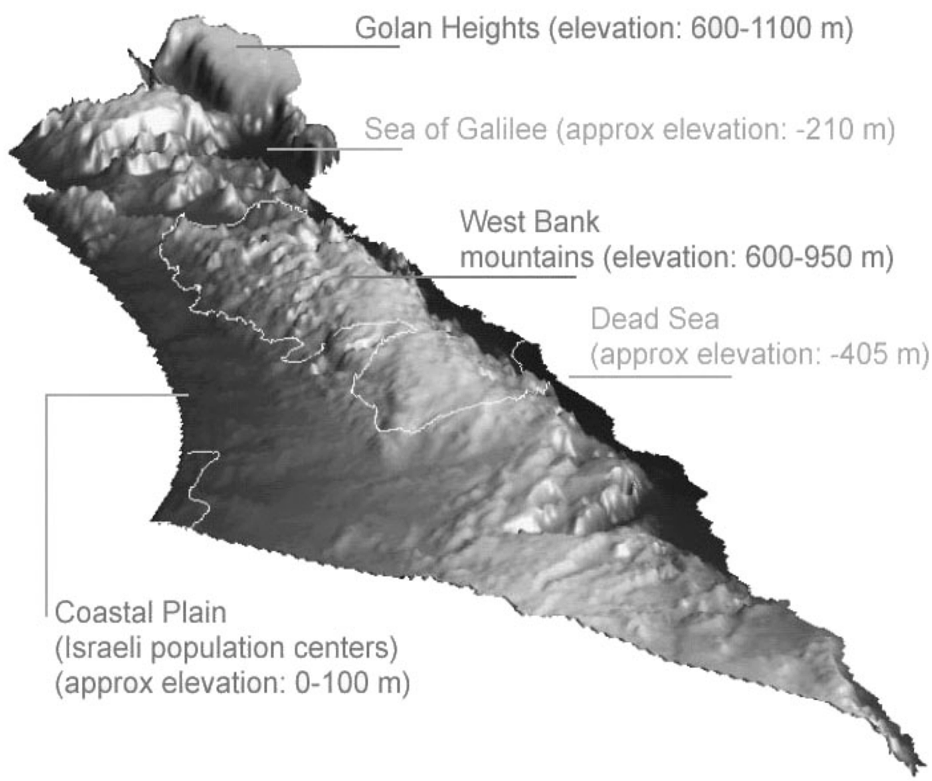

Figure 4. Topography of Israel, the West Bank, Gaza Strip, and Golan Heights, rendered in 3-D with a vertical exaggeration of approximately 50x.

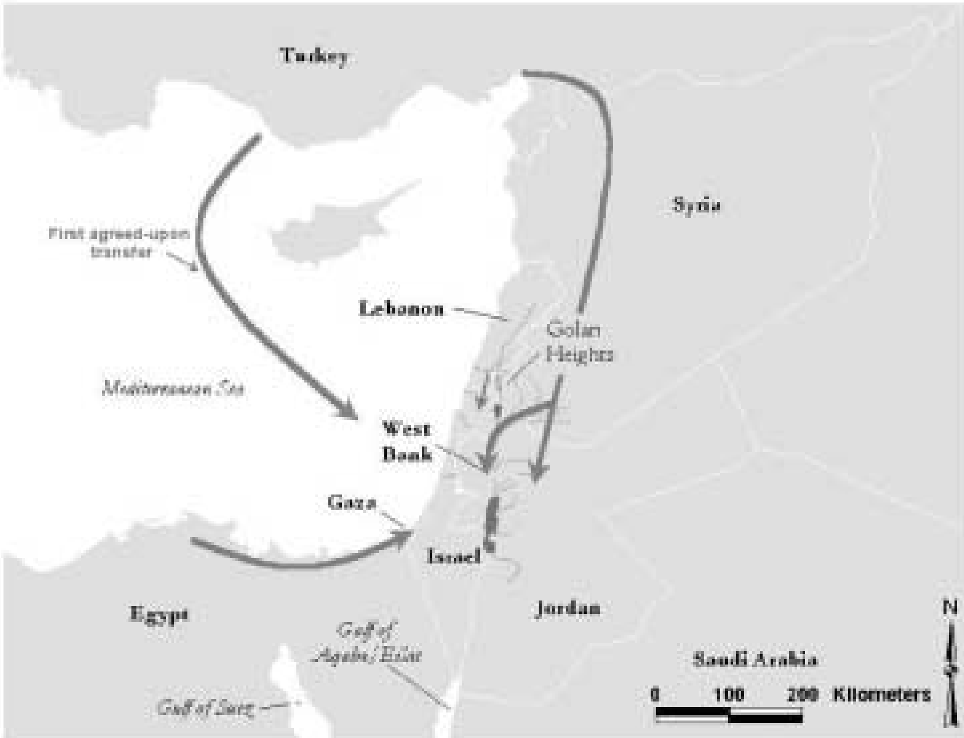

Figure 5. Possible international water transfers in the Eastern Mediterranean.

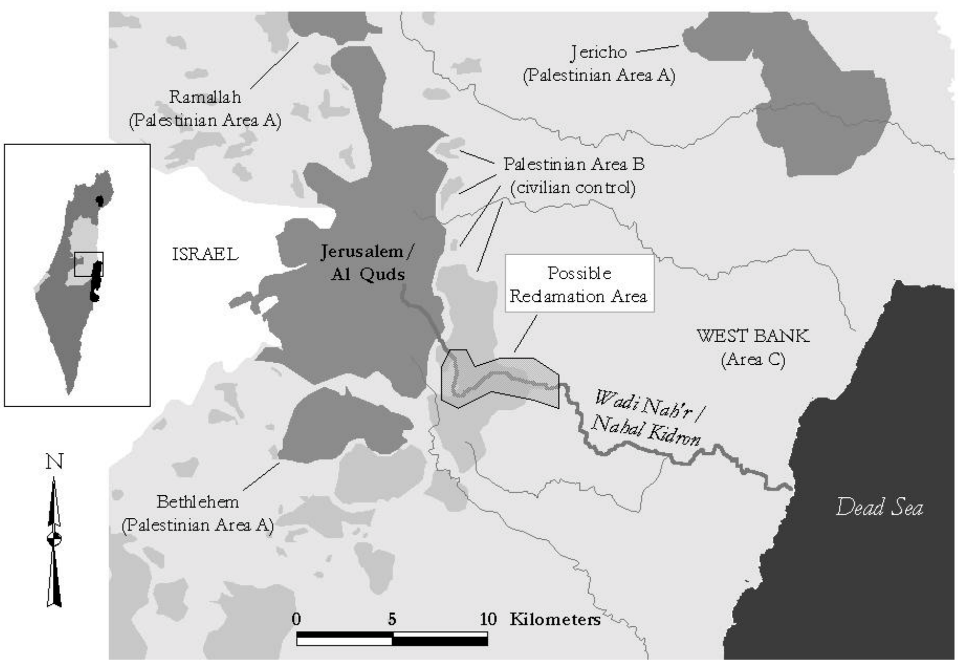

Figure 6. Wadi Nah’r / Nahal Kidron joint reclamation area (proposed).

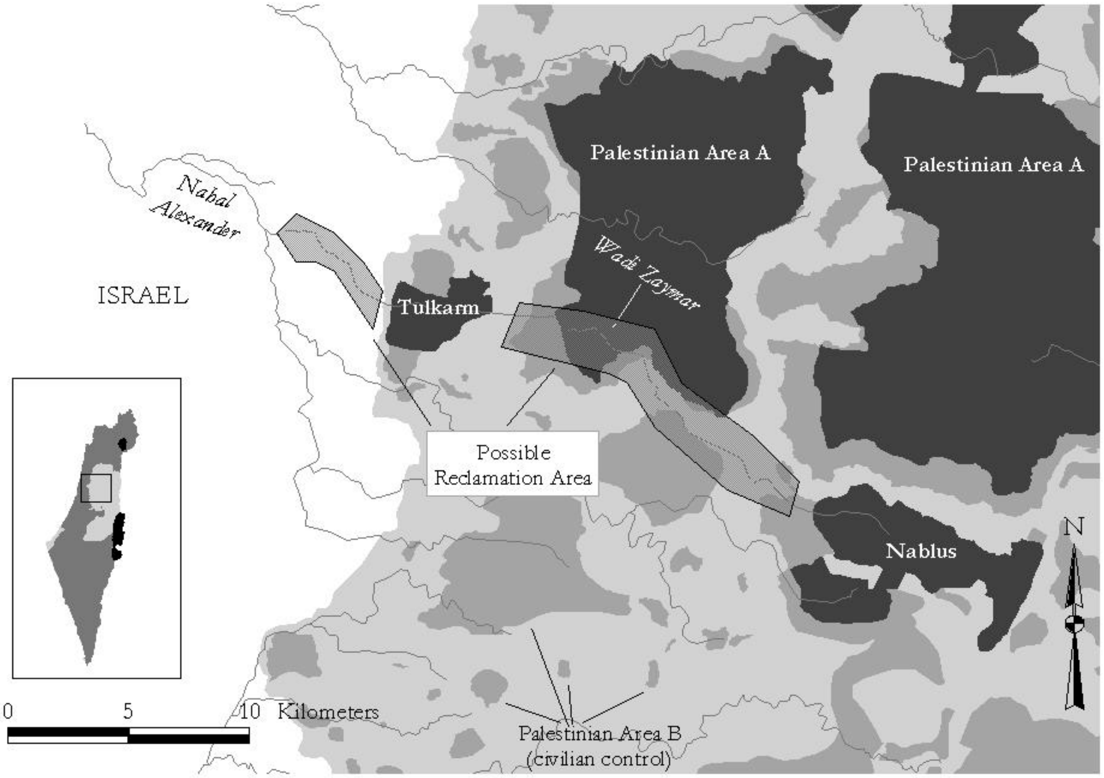

Figure 7. Wadi Zaymar / Nahal Alexander joint reclamation area (proposed).